4. Shcherban A. N., Kremnev O. A. *Nauchnye osnovy rascheta i regulirovaniya teplovogo rezhima glubokikh shakht* (Scientific bases for calculation and control of thermal environment in deep mines), Kiev: Ukrainian SSR Academy of Sciences Press, 1959, Vol. 1, 430 p.
5. Shcherban A. N., Kremnev O. A. *Nauchnye osnovy rascheta i regulirovaniya teplovogo rezhima glubokikh shakht* (Scientific bases for calculation and control of thermal environment in deep mines), Kiev: Ukrainian SSR Academy of Sciences Press, 1959, Vol. 2, 347 p.
6. Goncharov S. A., Dmitriev A. P. *Termodinamicheskie protsessy v gornykh porodakh* (Thermodynamic processes in rocks). Moscow: Nedra, 1990, 330 p.
7. Kazakov B. P., Zaitsev A. V., Shalimov A. V. Vliyanie zakladochnykh rabot na formirovanie teplovogo rezhima v gornykh vyrabotkakh v usloviyakh rudnikov OAO "Norilski Nikel" (Influence of backfilling on thermal conditions of underground excavations in terms of Norilsk Nickel MMC mines), *Vestnik Permskogo natsionalnogo issledovatelskogo politekhnicheskogo universiteta. Geologiya. Neftegazovoe i gornoe delo—Perm National Research Polytechnic University Bulletin. Geology. Oil&gas production and mining*, 2012, No. 2, pp. 110–114.

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RESEARCH OF SALT ROCKS GAS CONTENT OF III POTASH LAYER IN THE KRASNOSLOBODSKY MINE FIELD

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The article reports the data of experimental studies into gas content of Potash Salt Horizon 3 put on production in Krasnoslobodsky Mine belonging in Mine Group-2 of Belaruskali OJSC. The gas content of Potash Salt Horizon 3 is quantitatively estimated in terms of free and occluded gas, and chemical composition of free gas is analyzed.

Key words: *potash horizon, sylvinite layer, clay–carnallite unit, gas content of rocks, free gas, chemical composition.*

The development strategy of Belaruskali OJSC over the period to 2020 stipulates the ore stock sustaining and accretion with intent to increase the rated output of potash fertilizers up to 12.5 Mt per year. Within the framework of the strategy and toward the sustained capacity of Mine Group-2, Krasnoslobodsky Mine was commissioned in December 2012, at annual design capacity of 6 Mt and the term of life no less than 35 years.

The minefield of Krasnoslobodsky Mine is situated on the northwest of the Starobinsky potash salt deposit (Fig. 1). It adjoins the Mine Group-2 minefield on the east and is bounded by Potash Salt Horizon 3 on the west.

The structure and tectonics of the Krasnoslobodsky minefield area of the Starobinsky deposit feature two northeastern strike faults that split the potash deposit into extended blocks step-plunging west–eastwards.

Potash Salt Horizon 3 (PSH 3) is the main pay horizon of Krasnoslobodsky Mine. The horizon is 16 to 18 m thick in the center of the minefield and to 1 m thick at the edges. The occurrence depth of the horizon varies from 477 to 848 m below surface. PSH 3 consists of three units: the top sylvinite unit is classified non-commercial reserves due to high insoluble residue content; mid clay–carnallite unit is composed of alternating rock salt, clay and carnallite; and bottom sylvinite unit is six sylvinite layers with rock salt bands.

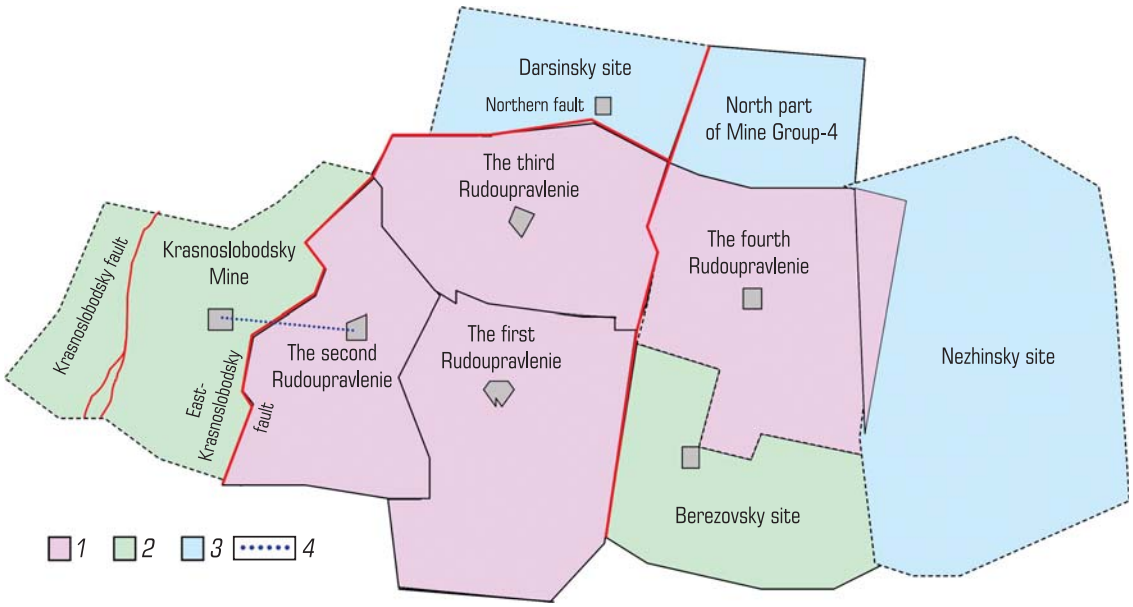

Fig. 1. Layout of Belaruskali JSC minefields at the Starobinsky potassium deposit:
1 — operating mines; *2* — mines under construction; *3* — areas planned for extraction; *4* — conveyor track

The bottom commercial sylvinite bed contains 6 sylvinite layers (1, 2, 3, 4, 5, 6) and rock salt bands (1–2, 2–3, 3–4, 4–5, 5–6). Sylvinite layers 1, 5 and 5 are outbalance, and layers 2, 3 4 form PSH 3.

Krasnoslobodsky Mine extracts PSH 3 by selective longwall slicing with backfilling and separate preparation of slicing longwalls, using power-activated machine complex, including SL-300NE and SL-300S shearer loaders.

According to mining practice at Belaruskali JSC, mining on PSH 3 induces gas-dynamic event: rock salt and gas outbursts, roof rock falls (floor rock failure), face rock squeezing-out with air blast and fracture and blow-out of rocks into drives. The sudden and very strong gas-dynamic events (GDE), producing scattering rock fragments and combustion gas emission in combination with air blast, constitute menace to health and life of miners, destroy expensive equipment and disorder mine operation. In compliance with regulatory requirements on safety of mining in GDE-hazardous conditions, Krasnoslobodsky Mine has undertaken analysis of gas content of PSH 3 and enclosing salt rocks.

Since 1960s many research institutes analyzed gas content of PSH 3 at the Starobinsky potash deposit [1–5]. According to the research findings, PSH 3 gas content ranges between 0.032 and 0.83 m^3/m^3. The clay–carnallite unit gas content varies from 0.15 to 3.92 m^3/m^3, at the average value 1.8 m^3/m^3. There is a free methane–nitrogen layer, with nitrogen content of 93 % and methane content not higher than 6 %. Gas content of PSH 3 and enclosing rocks within the limits of Krasnoslobodsky Mine of Mine Group-2 has not been studied down to recent times.

The gas content and free gases of PSH 3 and enclosing salt rocks were studied by means of instrumental observations in boreholes and shotholes 42 mm in diameter, with free gas sampling using the procedure described in [6]. The studies were carried out in the shaft bottom, in the main northward and eastward roadways, main southward roadways, main northward air roadway, main eastward roadways, developing entries of northeastward panel no. 1 — haulage, ventilation and conveyor drifts, as well as in brine accumulator — to estimate gas content of PSH 3 rock salt underlayer and clay–marly horizon XII. The observation holes (horizontal and vertical) were drilled in walls, roofs and floors of roadways driven on PSH 3. The drilled holes were spaced at 1 m and sealed at 0.5 m from the bottom. The holes were 3 to 6 m long. Emitted gas in the sealed part of the holes came in gas outlet fitting connected to gas emission rate predication device PG-2MA. The device specification is: initial gas emission rate range—from 0.5 to 25 l/min; emitted gas pressure range — from 0.02 to 0.15 MPa; error — ±10%. In 30 s after the hole sealing, the device measured the hole gas pressure excess over the atmospheric pressure, i.e., the initial gas pressure. In addition, gas emission rate and the rate change time were measured. The volume of the emitted gas was related with the volume of the hole drainage area. The analysis of the chemical composition of free gases, after vacuum sampling, used Varian 450-GC gas chromatographs with Galaxie software (version 1.8 or higher) that handled data processing, temperature setting, pressure control of the gas-carrier and other working gases, gas valve switch and control of peripheral equipment.

Occluded gas content of PSH 3 and enclosing rocks was estimated using the dissolving method [6].

Figure 2 shows the gas content distribution in geological profile of PSH 3, within the limits of extraction pillar of longwall no. 1. The free gas content of salt rock is low and varies from 0.11 to 0.23 m^3/m^3. The gas content increase upward the geological profile is apparent. The maximum gas content is observed in sylvinite layer VI. The gas

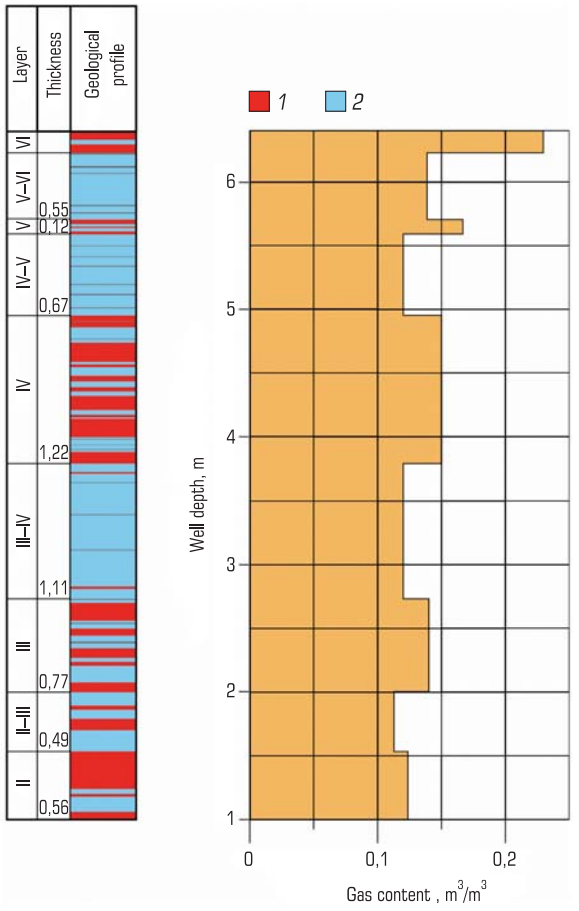

Fig. 2. Gas content distribution in geological profile of Potash Salt Horizon 3 (Krasnoslobodsky Mine, extraction pillar of longwall no. 1):
1 — sylvinte; *2* — rock salt

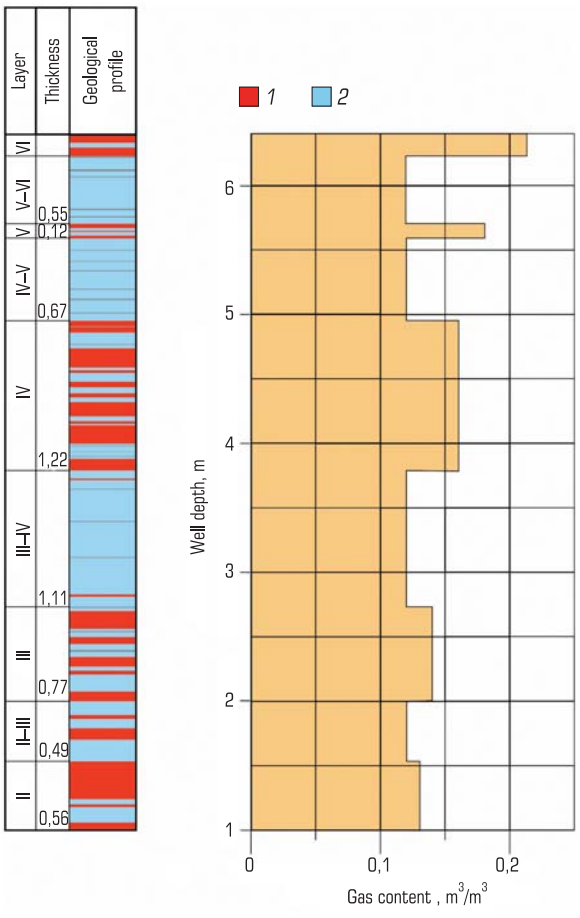

Fig. 3. Gas content distribution in geological profile of Potash Salt Horizon 3 (Krasnoslobodsky Mine, main ventilation drift no. 1 (*1* and *2* are the same as in Fig. 2)

content distribution over the geological profiles of the other areas in Krasnoslobodsky Mine is analogous (Fig. 3).

The details of the gas content and gas emission rate in PSH 3 and enclosing rocks in Krasnoslobodksy Mine, Mine Group-2 are given below.

Rock	Gas content, m^3/m^3	Gas emission rate, dm^3/min
Sylvinite layer VII	*0.17–0.31*	*0.1–0.12*
Rock salt band 6–7	*0.12–0.16*	*0.05–0.7*
Sylvinite layer VI	*0.11–0.24*	*0.07–0.12*
Rock salt band 5–6	*0.11–0.17*	*0.05–0.07*
Sylvinite layer V	*0.12–0.19*	*0.05–0.1*
Rock salt band 4–5	*0.1–0.14*	*0.05–0.07*
Sylvinite layer IV	*0.11–0.31*	*0.07–0.13*
Rock salt band 3–4	*0.1–0.14*	*0.05–0.06*
Sylvinite layer III	*0.12–0.25*	*0.07–0.1*
Rock salt band 2–3	*0.11–0.21*	*0.05–0.1*
Sylvinite layer II	*0.13–0.21*	*0.05–0.09*
Rock salt band 1–2	*0.1–0.2*	*0.05–0.07*
Underlying rock salt	*0.1–0.14*	*<0.2*
Clay–marly horizon XII	*0.1–0.23*	*<0.34*

Fig. 4 describes chemical composition of free gases in sylvinte layer IV of PSH 3. The gas composition features increased content of heavy hydrocarbons. Generally, free gases are methane and nitrogen, no hydrogen is found.

Thus, the gas content of PSH 3 in Krasnoslobodsky Mine of Mine Group-2 is low. At the same time, accumulations of free gases at the boundaries of clayey bands and layers and at the junction of the underlaying rock salt and clay–marly horizon XII require assessment of possibility of gas-dynamic events in roofs and floors of development entries and breakage headings on PSH 3. For safe mining in excavations where roof and floor rocks contain gases, the roof rock stability is to be estimated in terms of the minimum force sufficient for the roof rock unbalance.

The probability of gas-dynamic events in roofs and floors of excavations driven on PSH 3 was estimated by the procedure from

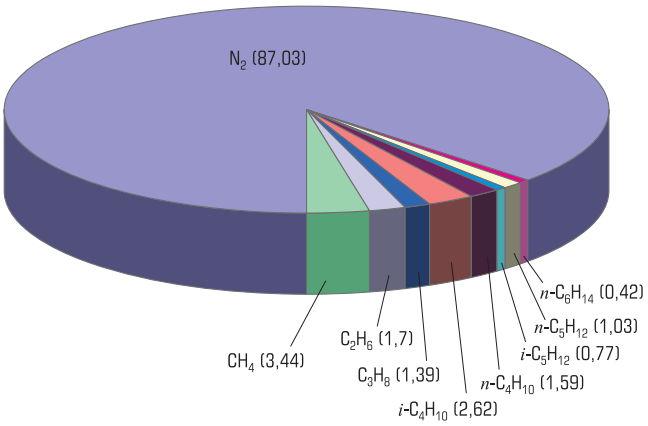

Fig. 4. Chemical composition (%) of free gases in sylvinite layer IV of Potash Salt Horizon 3

[7]. It has been found that at relatively low pressure of free gas accumulations at the boundaries of the layers of PSH 3, with and without considering the "delay" effect, it is possible that gas-dynamic events develop in roof rocks in the face area and out of the face area of excavations. Prevention of gas-dynamic events in the roofs of the mine excavations demands for preventive draining out of gasses in the roof rocks.

Based on the studies of the gas content and gas-dynamic characteristics of roof rocks in mine excavations, parameters for short and long degassing hole drilling have been developed for the conditions of Krasnoslobodsky Mine of Mine Group-2. As compared with the preventive degassing hole drilling in the other potash mine of Belaruskali JSC, the short hole spacing in the roof rocks in excavations on sylvinite layer IV and above has been increased from 1 and 1.2 m to 2.5 m. Besides, the length of the degassing holes in the roofs of developing entries on sylvinite layer IV has been shortened from 6 and 4 m to 3 m. The introduction of the new parameters of the preventive degassing hole drilling has enabled the increased rate of advance in developing entries and ensured draining of free gas accumulations in roof rocks at the boundaries of rock layers.

References

1. Cherepennikov A. A., Bozhkovskaya T. K. *Issledovanie gazonosnosti Tretiego kaliynogo gorizonta Pervogo Soligorskogo rudnika* (Analysis of gas content of Potash Salt Horizon 3 in Soligorsk Mine-1. Trudy VNIIG—VNIIG Transactions, 1969, Issue 51, pp. 135–139.
2. Fiveg M. P., Fomina V. D. *Gazoproyavleniya v vyrabotkakh Pervogo Soligorskogo rudnika* (Gas shows in drives of Soligorsk Mine-1). Trudy VNIIG—VNIIG Transactions, 1969, Issue 51, pp. C. 49–62.
3. Polyakov L. F., Krasnokutsky N. P., Zhevzhik E. P. Gazonosnost Tretiego silvinitovogo plasta na Soligorskikh kaliynykh rudnikakh (Gas content of the sylvinite layer 3 in Soligorsk potash mines). *Gorny Zhurnal—Mining Journal*, 1971, No. 9, pp. 68–71.
4. Lidin G. D. O gazonosnosti kaliynykh solei Belorussii (Gas content of potassium salts in Belarus). *Gorny Zhurnal—Mining Journal*, 1974, No. 12, pp. 55–58.
5. Zemskov A. N. *Gazonosnost produktivnykh plastov Soligorskikh kaliynykh rudnikov* (Gas content of productive strata in Soligorsk potash mines). Trudy VNIIG—VNIIG Transactions, 1988, pp. 32–40.
6. Zemskov A. N., Kondrashev P. I., Travnikova L. G. *Prirodnye gazy kaliynykh mestorozhdeniy i mery borby s nimi* (Natural gases of potash deposits and methods of natural gas control). Perm, 2008. 414 p.
7. Proskuryakov N. M., Kovalev O. V., Meshcheryakov V. V. *Upravlenie gazodinamicheskimi protsessami v kaliynykh rudnikakh* (Gas-dynamic control in potash mines). Moscow: Nedra, 1988. 239 p. DK

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